MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
NATIONAL AVIATION UNIVERSITY
FACULTY OF AIR NAVIGATION, ELECTRONICS, AND TELECOMMUNICATIONS

DEPARTMENT OF AVIONICS

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‘___’___________2022

GRADUATION WORK

(EXPLANATORY NOTES)

FOR THE DEGREE OF BACHELOR
SPECIALTY 173 ‘AVIONICS’

Theme: ‘Crew training system for action in special cases of flight’

Done by:	__________ (signature)	I.O. Gorbachov
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Kyiv 2022

МІНІСТЕРСТВО ОСВІТИ І АУКИ УКРАЇНИ
НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ
ФАКУЛЬТЕТ АЕРОНАВІГАЦІЇ, ЕЛЕКТРОНІКИ ТА ТЕЛЕКОМУНІКАЦІЙ
КАФЕДРА АВІОНІКИ

ДОПУСТИТИ ДО ЗАХИСТУ
Завідувач випускової кафедри
_________С.В. Павлова
«___»___________2022

ДИПЛОМНА РОБОТА

(ПОЯСНЮВАЛЬНА ЗАПИСКА)

ВИПУСКНИКА ОСВІТНЬОГО СТУПЕНЯ БАКАЛАВР
ЗА СПЕЦІАЛЬНІСТЮ 173 «АВІОНІКА»

Тема: «Система підготовки екіпажу до дії в особливих випадках польоту»

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Київ 2022

TASK for execution graduation work

I.O.Gorbachov

1. Theme: ‘Crew training system for action in special cases of flight’ , approved by order №352/ст of the Rector of the National Aviation University of 04 April 2022.
2. Duration of which is from 16.05.2022 to 16.06.2022.
3. Input data of graduation work: Modern crew training system, their pros and cons. Basics of decoding flight information on complex aircraft simulators. Actions of the crew during emergency situations on board.
4. Content of explanatory notes: List of conditional terms and abbreviations; Introduction; Chapter 1: Basics of decoding flight information on complex aircraft simulators; Chapter 2: General principle and the role of the human factor in safety management; Chapter 3: Development of a flight parameters processing system and recommendations for aircraft crew training.
5. The list of mandatory graphic material: figures, charts, graphs.

1. Planned schedule

№	Task	Duration	Signature of supervisor
1.	Validate the rationale of graduation work theme	18.05-20.05	
2.	Carry out a literature review	21.05-24.05	
3.	Develop the first chapter of diploma	25.05-29.05	
4.	Develop the second chapter of diploma	30.05-03.06	

5.	Develop the third chapter of diploma	04.06- 08.06	
6.	Tested for anti-plagiarism and obtaining a review of the diploma	09.06- 16.06	

1. Date of assignment: '____'___________ 2022

Supervisor _______________

(signature) (surname, name, patronymic)

The task took to perform _______________

(signature) (surname, name, patronymic)

ABSTRACT

The explanatory notes to the graduate work ‘Crew training system for action in special cases of flight’ contained 60 pages, 11 figures, 2 tables, 16 information source.

Keywords: FULL FLIGHT SIMULATOR, CREW, DISTRIBUTION, INCIDENT, SAFETY, TRAINING, DECODING, ANALYZING.

The purpose of the graduate work is to study the essence of the system of preparing the crew for action in special cases of flight, finding solutions to improve it.

The object of the research is the process of controlling the flight crew training system.

The subject of the research are flight crew training system, aviation simulators.

Research Method - conducting research aimed at studying the system of crew preparation for action in special cases of flight and its improvement.

Thesis plan

LIST OF CONDITIONS, SHORT TERMS, TERMS

FFS- Full Flight Simulator

FDR- Flight data recorder

BAFDA- British Airways Flight Data Analysis

CWT- Crew Work Technology

QAR- Quick Access Recoder

WQAR- Wireless Quick Access Recoder

FDAU- Flight Data Acquisition Unit

ATC- Air Traffic Control

TCAS- Traffic Alert and Collision Aviodance

DFDR- Digital Flight Data Recorder

ICAO- International Civil Aviation Organization

CA- Civil Aviation

FCOM- Flight Crew Operating Manuals

CRM- Crew Resource Management

LOFT- Line Oriented Flight Training

SOP-Standard Operating Procedure

RFP- Request For Proposal

NTS- Negative Torque Sensing

SC- Safety Culture

FDIU- Flight Data Interface Unit

FDAC- Flight Data Acquisition Card

SSFDR- Solid State Flight Data Recorders

DAR- Direct Access Recorders

DMU- Data Management Units

CVR- Cockpit Voice Recorder

CPU- Command Processor Unit

AS- Airworthiness Standards

GPWS- Ground Proximity Warning System

Introduction

Theme of the diploma project: Crew training system for action in special cases of flight.

Actuality of theme. As we can see, flight safety standards are improving every year, but despite the best efforts of engineers, psychologists and scientists around the world, there is still a chance of an emergency during the flight due to the technical condition of the aircraft or human factor, so the crew must always be ready for various challenges to ensure its own safety and the safety of passengers. This topic is quite relevant, as it will allow to analyze the shortcomings of the crew training system in special flight cases and will allow to implement improvements in flight safety standards as soon as possible.

Purpose of the work: to study the essence of the system of preparing the crew for action in special cases of flight, finding solutions to improve it.

Object of research: the process of controlling the flight crew training system.

Subject of research: flight crew training system, aviation simulators.

Research methods: conducting research aimed at studying the system of crew preparation for action in special cases of flight and its improvement.

Chapter 1: Basics of decoding flight information on full flight simulators.

In order to begin to study all aspects of the basics of deciphering flight information on full flight simulators in this chapter, it is first necessary to understand what an full flight simulator is.

Full flight simulators (FFS) are called simulators equipped with a mobility system. These are simulators of the highest level. The cabin of the complex simulator is made in the form of a real cabin of the aircraft. Advanced visualization systems are installed on FFS. Such simulators implement training at a more advanced level and have the following main properties: the maximum approximation of the conditions of the pilot to the conditions of actual activity in flight; ensuring that all the tasks of the pilot's actual activity, which he performs in flight, are practiced on the simulator as a whole; ensuring the possibility of objective control of the results of all working on a comprehensive simulator tasks in general. The full flight simulator is the highest level of technical means of training for flight crew training and has the ability to practice all, without exception, the modes of operation of the aircraft.

Fig. 1.1. Full Flight Simulator

In this chapter we will learn about the aspects of technical operation of FFS, the essence and classification of means of decoding flight information on FFS and learn in detail how the decryption system works based on Air Astana data.

1.1 Essence and classification of means of decoding flight information on full flight simulators.

The main tasks of decoding flight information on complex aircraft simulators are:
1.Monitoring the technical condition of aircraft

The purpose is to provide information on the processes of maintaining the airworthiness of aircraft, the required level of reliability of aircraft.

2. Analysis of the causes of accidents and incidents

The goal is to develop preventive measures to prevent them.

3. Flight control

The purpose - information support of processes of maintenance of required quality of work of crew, prevention of deviations and infringements in its actions.

Decryption of flight information on the FFS is the account of Airborne Flight Information Systems, which in turn are divided into emergency and operational. Emergency and operational systems are of two types: parametric, sound. There are three types of sound: magnetic, optical (laser) and hard crystal, when the parametric are divided into magnetic, hard crystal, mechanical recording and phase recording.

There are the following types of flight information processing using Airborne Flight Information Systems:

1. Automated primary processing - reproduction decoding, decoding and documentation in physical quantities of encoded source information. It is performed when it is impossible to process flight information according to the express analysis program.

2. Express analysis - is the main type of processing, in which the decryption and analysis of recorded information are automatically performed to identify deviations in the movement of aircraft from flight restrictions set by the flight crew operation manual, deviations in the actions of the crew from the established technology of its work, failures, failures, malfunctions in the operation of functional systems and power plants of the aircraft.

3. Automated secondary processing - the use of specialized programs for in-depth analysis, systematization and generalization of processing results (for example, with the implementation of calculation methods to determine the spatial trajectory of aircraft or assess and predict the technical condition of aircraft). Performed: in the investigation of incidents; in case of failures of aircraft systems and equipment; if necessary, analyze the reliability of express analysis messages.

4. The module of control of operability - control of a technical condition of aircraft systems: engines; control systems; power supply systems; hydraulic systems; pressure control systems; fire system and smoke alarm system; fuel system; aeronautical navigation equipment; automated onboard control system, etc.

5. Pilot control module - control of departure for flight and operational restrictions of the following parameters:

- aircraft mass, flight speed and number M, vertical overload, roll and pitch angles, flight altitude;
- maintaining the recommended modes of control of the power plant, speed, altitude, sequence of actions, the position of the chassis, flaps, flaps, stabilizer, interceptors, the operation of aircraft systems.

1.2 Analysis of the literature on the interpretation of flight information on full flight simulators and taking into account the human factor.

Airborne Flight Information Systems of Air Astana consists of an aircraft-installed flight data recorder (FDR), an installed British Airways Flight Data Analysis (BAFDA) program and, as a backup system, Aerobytes. BAFDA converts the digital parameters into an appropriate format suitable for analysis, plotting and visualization of the received data in order to simplify the evaluation of flight events. The analyzed flight parameters help to determine if the aircraft operating limits have been exceeded and if deviations from CWT have occurred. The parameters monitored in flight events are values that reflect the requirements of the current regulations of Air Astana and introduced into the program to facilitate the process of identifying and assessing risks that threaten flight safety. The limit values for the parameters for detecting flight events are constantly reviewed and updated in accordance with the current regulatory documents.

The following equipment is used for efficient transferring of data:

- FDR is a device installed on board the aircraft for reading and writing a large number of various flight parameters and one-time commands.

- Quick Access Recoder (QAR) and Wireless Quick Access Recoder (WQAR) are the means to transmit data recorded on board an aircraft to a ground server.

- BAFDA is a computer system (software) for deciphering and analyzing flight parameters (data), identifying deviations from normal values, compiling statistical reports to facilitate the interpretation of the analyzed data, etc. Also, this software provides the ability to reproduce all available flight parameters by visualizing them, both for its analysis and for the purpose of debriefing with the crew.

Equipment:

- FDR is a device installed on board an aircraft and designed to record flight parameters received from the FDAU (Flight Data Acquisition Unit), which also transmits flight data either to an electronic unit (QAR) installed in an easily accessible place, from which it is made The process of capturing recorded flight parameters, or to a device for wireless transmission of recorded flight parameters.

- QAR or WQAR do not have anti-shock protection and are installed on the aircraft if necessary, such units record the flight parameters either on removable low-cost media, or transmit the recorded parameters to the server using wireless communications (Teledyne).

Computer system for the analysis of flight parameters:

- Files with flight parameters are uploaded from the aircraft recording device to the Air Astana computer system server, then the server automatically transfers the data to the BAFDA and Aerobytes program for processing using analytical software, where this confidential information is stored and is under constant protection from unauthorized access to it .

- BAFDA software facilitates day-to-day analysis of flight parameters to identify deviations that may require urgent action to prevent them.

- The BAFDA software checks the uploaded data for any deviations. To identify deviations, logical formulas are usually used, made up of a large number of absolute values and design parameters, which are obtained from various sources, such as aircraft performance curves, CWT, engine performance, aerodrome flight patterns and approach features. Some of the simplest logic formulas are designed to control deviations from normal values, such as readings in the red (dangerous) zone or operating limits. The values entered into the logic formulas to control deviations from normal values are determined by the Air Astana Flight Operations and Compliance Departments.

- Normal flight parameters and all deviations from the norm are displayed on the computer screen in various formats. The decoded flight parameters can be presented by the program in a variety of ways, such as colored symbols, curves and straight lines, in the form of a sequential series of digital values, animation of instrument readings in the cockpit, animation of the aircraft flight, including the use of the Google Earth program.

One way to extract useful information from recorded flight parameters is to detect deviations, such as deviations from the operating limits of an aircraft flight manual or CWT. The list of flight events and parameters required for monitoring was determined taking into account the receipt of such data that are of the greatest interest to the flight operations department and the corporate security compliance department. Flight events associated with deviations from the norm represent factual information that can be supplemented by information from the crew and engineering staff. In Air Astana, the standard list of flight events that are mandatory for monitoring has been adapted in accordance with company-specific parameters, values and approved operating technologies. The parameter values used to determine deviations from the norm are constantly reviewed to reflect the current operating standards in force at Air Astana.

After processing the parameters received from the simulator FDRs, the system saves the data of all flights, and not just those related to significant events. The stored data allows you to select the necessary parameters to describe the characteristics of each flight and to conduct a comparative analysis of a large number of changing operational criteria. Emerging negative trends must be brought under control before the risk associated with deviation from the norm reaches a value above an acceptable level.

For all flights, the program conducts a comparative analysis to determine normal operating practices that can be accumulated by storing various types, including exemplary information from each flight. If the program detects flight events in the course of daily analysis, it is necessary to consider and check them in more detail to confirm their authenticity or fictitiousness. In this case, the main flight parameters are considered more carefully, for example, engine operation, speed, bank, pitch angle, etc., and the change in these parameters at different stages of flight. Such parameters can be compared with the parameters of other flights performed without deviations, which do not require verification. After a detailed study and comparison of parameters and, if necessary, consultation with pilots and engineers, a conclusion can be drawn about the reliability of the event in question.

After the data check is completed and deviations from normal operation have been determined taking into account environmental conditions, the technical condition of the aircraft, etc., the event must be acknowledged in the system, assessed by severity, marked with a keyword and protected from changes. The program accumulates confirmed flight events in a database (flight events module) to build various graphs and determine trends in various options, which contribute to deep and comprehensive analysis.

Reviews and summaries of data are produced on a monthly basis on a regular basis, but the investigation of individual significant flight events must be timely and action taken without delay. All data is analyzed to identify specific operational threshold exceedances and undesirable trends, which are reported to senior flight operations and training departments. Flight crews are informed of specific operational threshold exceedances and significant deviations on a daily basis via telephone or email by an authorized person.

In case of detection of deficiencies in piloting technique, the confidentiality of information about the crew must be maintained. Information about deviations is transmitted to specific flight crews through an authorized person - the manager of the flight data analysis department. When interacting with the crew, the authorized person clarifies the circumstances, receives information from the crew's words and gives advice and recommendations for taking appropriate measures, such as additional training of the flight crew, making changes to manuals and instructions, as well as changes to the technological instructions of airports and ATC services .

All flight events in the database are subject to archiving. This database is used to sort information, confirm it and present it in the most understandable form for the command and control staff. It is only after a certain period of time that the accumulated information gives a picture of emerging trends and risks that otherwise might not have been identified.

The experience gained in the process of operation is used by the airline in measures to improve flight safety. Any information must be used with care, bearing in mind that the consent of all crew members is required for the identification of a flight event before it is used for additional training or in activities to improve flight safety. The data analysis department staff needs to program the correct parameter thresholds for determining deviations from the norm, providing for acceptable inaccuracies in order to exclude the fixation of minor deviations, false events and at the same time provide an appropriate minimum range for aircraft operation according to CWT, but without pushing the crew to focus on parameters to avoid deviations.

As in any closed process, where control over the implementation of preventive measures is necessary, they need to be evaluated for effectiveness. Crew feedback is essential for identifying and resolving safety issues, which may include questions such as:

- Are the implementation and effectiveness of preventive measures in line with safety requirements?
- Is the level of risk reduced or inadvertently moved to another area of operations?
- What new problems have appeared in flight operations as a result of the implementation of preventive measures?

All successes and failures in the implementation of the program must be recorded by comparing the planned goals with the results achieved. This will provide a solid database for revision and a foundation for future development of the program.

Software provided by British Airways Flight Data Analysis (BAFDA). This software has instructions for its use that meet the following requirements:

- A complete process has been created by which an encrypted block of flight data is converted into readable and useful information;

- Provision of the programming device with the function of detailed information decoding to convert it into the required format and further analysis using the software. The BAFDA Program Manual provides detailed hardware specifications that include an in-depth look at the process of extracting information from a flight data block. This document is drawn up as a separate part of the contract for the supply of the system, which, if necessary, will be changed and supplemented as the software is improved and developed.

The manual covers the processes of downloading and transferring data, monitoring the performance of the program and statistics of processed data, using statistical modules, determining exceedances of operational limits (distribution of responsibility, results of investigations, measures taken, ASR data, etc.), archiving and recordings made by users programs. For the successful operation of the BAFDA program, the supplier provides full documentation of its design and detailed instructions for use, understandable to users. Changes, innovations and elimination of shortcomings of the program are described in detail with the dates of their introduction.

At the initial stage of the formation of the BAFDA program, a test is made to process encrypted records and convert them into engineering units. The next step is to perform an outlier detection test by manipulating the normal parameters to simulate an event, lowering the threshold values until the normal parameters show an excess (event), but an even more acceptable way is when old records with known values are processed. deviations, which should be identified by the program. To ensure that the program works well after significant changes to it, a routine check is necessary to detect and correct unforeseen problems that have arisen in the process of changes.

The basic set of events guaranteed by the BAFDA Program Provider has been updated in accordance with Air Astana's Crew Work Technologies (CWT). In the future, with changes in the CWT, the corresponding adjustments will also be made in the program. To meet the needs of Air Astana to better manage specific risk areas, new events have been added that are not included in the basic set of BAFDA events.

In addition to determining deviations, BAFDA additionally allows monitoring of any flight parameters during normal operation using the MaxVal module, which can be used by Air Astana in the near future to identify negative trends before they go to the event level. This module provides an opportunity for a thorough analysis of all available information broken down by time, place of operation, aircraft weight, flight stage, etc. and is of great practical importance for more accurate analysis than when only event flights are used.

1.3 Basics of operation of full flight simulators (FFS).

Specialists need to constantly confirm the parameters for compliance. Most of the parameters are viewed in each flight as they should be checked visually by the program and specialists. Some parameters are used in more complex events or investigations where more detailed analysis is required, so such parameters should be validated whenever a case is presented. The last group of parameters is very rarely used by the program to generate alarm events, infrequently used flight modes, etc., which can only be checked using a sophisticated mechanism in a technical laboratory, and such checks must be made at each compliance test and re-testing. certification of training recorders. Commonly used parameters: altitude, pitch angle, airspeed, acceleration, heading, controls, main modes of the automatic flight system, etc. Rarely used parameters: occasionally used modes of the automatic flight system, aircraft proximity alarm (TCAS), backup channel for extending flaps, etc. Difficult to check parameters: fire alarm, N1 overspeed, engine exhaust gas temperature high, low hydraulic pressure alarm, etc. If errors are found in the basic range of parameters, it is necessary to replace the hardware or software, and if the error in the parameters is short-term and the reason for this is a faulty sensor, then the faulty equipment must be replaced. An example of a sensor error can be explained using the design of a vertical acceleration sensor when it accidentally stalls and has a deviation from the original value at rest, say 1.3 and not 1.0, or vice versa, the damper does not work, so the sensor becomes overly sensitive. Data extraction error example: can be explained using a vertical acceleration sensor where a sample is taken every second, but the digital trend every second does not match the trend of the rest of the data. The reason for this may be the system, which records the measurement taken from the previous seconds of the series of measurements.

The analyst needs to be able to detect what data is different from normal or out of the ordinary. To do this, the Analyst must know how the parameters change in a normal flight and the possible range of their change for a certain flight stage.

BAFDA must monitor the quality of parameter recording and report any sensor failure to the department in writing. For successful operation, specialists are required to monitor the performance of on-board equipment that records flight parameters. Appropriate inspections and performance tests must be carried out at specified intervals.

Annual inspections of DFDR equipment on E-190 and B-757/767 aircraft must be carried out on a periodic maintenance form (C-check). The annual inspection of the DFDR equipment on A-319/20/21 aircraft according to SEMD-129/05 is not required because all parameter data that is stored in the on-board digital flight recorder is checked by the internal DFDR=BITE equipment. As soon as the "Read Parameters-After-Write" test reveals a discrepancy between the encrypted records in the recorder and the read records of the cipher words, the BITE system marks the recorder as faulty and a message appears on the crew display.

Records of the annual check of the recorders are the document on the basis of which the renewal of the flight recorder certificate and the renewal of the aircraft airworthiness certificate are made.

The Commission checks the simulator for compliance with the characteristics set forth in the Manual of the International Civil Aviation Organization (ICAO) on the criteria for the qualification assessment of flight simulation simulators (ICAO Doc 9625) (clauses 6 - 7 of the Procedure) [3]. Flight evaluation of the simulator includes evaluation of:

- compliance of the interior and equipment of the simulator cabin with the interior and equipment of the cockpit of a civil aircraft (CA), the flight of which is simulated by the simulator;
- flight simulation in accordance with the requirements of the documentation for the CA, which determine the rules for its operation under normal conditions (without simulation of failures of the CA systems and emergency situations);
- simulation of failures of CA systems, the simulation of which is provided by the simulator; • imitation of the out-of-cabin visual environment;
- simulation of acceleration effects;
- imitation of the acoustic environment;
- the possibility of using the simulator to perform training for working out actions in situations and flight modes that are mandatory for training members of the flight crews of the CA system and monitoring their professional skills in accordance with the requirements of FAP-128 and FAP-147 (clause 11 of the Order).

The technical evaluation of the simulator includes:

- verification of documents for the simulator;
- testing of systems and software of the simulator in accordance with the test program (clause 12 of the Order).

In p.p. 13 - 21 of the Order, documents are indicated that must be drawn up by the Commission based on the results of the test of the simulator. Based on these documents, the operator determines the list of types of possible training on the simulator and submits the specified list to the authorized body in the field of civil aviation, which makes a decision on the admission of the simulator within 30 working days (clauses 22 - 23 of the Procedure).

It is the responsibility of the operator to ensure that the simulator complies with the characteristics specified in the ICAO Manual of Criteria for the Qualification of Flight Simulation Training Devices. If it is impossible to ensure the compliance of the simulator with the specified characteristics, the operator is obliged to suspend the use of the simulator, and to resume its operation - to obtain a new permit, taking into account the new values of the characteristics of the simulator (clause 25 of the Order).

Chapter 2: General principle and the role of the human factor in safety management.

Crew training systems at a particular time of the day during the flight, and even more important storage safety of benefits. Pilots owe the guilt of the nobility, as if reacting to the folds of nature, the failure of electronic possession and on their own pardons. In addition, this chapter will analyze all aspects of crew training for special operations on FFS and the system for evaluating methods for such crew training. The second paragraph of this chapter will reveal the nutrition of the safety of health benefits and the injection of the human factor on the development of flight safety. Also, a lot of respect will be attached to those historical and technical developments in the field of parametrization.

2.1 Crew training systems in the event of a special flight incident.

As you know, the simulator is a model of a real object, which is designed to develop in the human operator the skills necessary to work with this object in real conditions, or to train certain functions, such as tracking, attention and more. Unlike a complex simulator, the functional one is not designed for accurate modeling of any specific system that the operator works with. It implements only the model that is necessary to improve a person's functional ability for a given activity. Analysis of the activities of operators shows that there are people who work effectively in normal conditions, successfully using their knowledge, skills and abilities in practice, but in emergency situations are confused and instead of quickly taking appropriate measures to eliminate the accident, make gross mistakes or completely removed from active action to normalize the situation. Given this, it is very important to determine the behavior of operators in such situations, select only suitable in this regard and ensure their training [13].

It should be noted that the methods of training pilots for FFS of western specialists are based on the concept of system process (input-process-output). Despite the availability of such scientific areas as operations research and systems analysis, there is still no generalized method for assessing the effectiveness of training processes, except for the assessment of economic efficiency. It is very important to study the relationship between flight safety and the effects of factor action. Both sequential action and simultaneous interaction of factors. The peculiarity of such relationships is that the criteria for the effectiveness of training in the management of countermeasures and anti-skills of pilots is the method of factor overlays and taking into account the impact of multifactoriality [11, 12].

Thus, we must train operators not only to act but also to counteract in special flight situations. To do this, there is training and checking the implementation of normal flight procedures and actions in emergency situations / Normal and abnormal / emergency procedures.

This training and testing is carried out in conditions as close as possible to real difficult weather conditions, such as icing, ice, bumpiness, high temperatures, etc., the actions and sustainable skills of the crew are practiced when:

- flight preparation and pre-flight operations;
- use of "CHECK LISTS";
- taxiing;
- takeoff, termination of takeoff at the maximum allowable wind;
- engine failure (fire) on takeoff between V1 and V2;
- various failures leading to serious complications of flight performance at its various stages, such as: fire (failure) of the engine, fire (smoke) in the cockpit or cargo compartments, engine start in flight, depressurization with emergency descent, crew incapacitation and other emergency procedures described in FCOM and taken into account in simulator training scenarios;
- approach and landing using various approach systems with and without automation (autopilot, autothrottle, flight directors, etc.) all running engines and with a failed engine, with a normal landing weight and with an excess of the maximum allowable landing weight;
- go-around from different heights with all engines running and with a failed engine;
- emergency evacuation.

1. Checking piloting technique and ability to act in an emergency / Skill test / Proficiency check. During the inspection, the instructor/examiner verifies and guarantees that the flight

crew members have acquired sufficient knowledge and skills to safely conduct flights in flight conditions at all stages, in various weather conditions and in any non-standard situations.

2. Training and checking for system failures that are not related to an emergency / System malfunctions. During training and testing, the actions and stable skills of the crew are worked out in case of failures of various aircraft systems that do not lead to an emergency. Simulator training scenarios have a cycle of three years and cover the development of actions in case of three years and cover the development of actions in case of the most complex failures of all aircraft systems, which are recommended by the aircraft manufacturer.

3. Training and verification according to the scenario of the situation of a real flight along the route / LOFT and assessment of resource management of the cockpit / CRM assessment.

Line Oriented Flight Training (LOFT) is a test of flight crews in the simulator according to a scenario as close as possible to real conditions with the implementation of typical daily procedures and requirements described in the SOP and the airline's RFP with the occurrence of atypical conditions that require competent decision-making, communication in the crew and leadership skills pilot. Therefore, this exercise combines a Crew Resource Management (CRM) assessment with NTS.

In order to have an accurate idea of how well the flight crew responds to various non-standard situations, the crew is not informed in advance about the scenario of the simulator session, but is provided with all the necessary flight documentation.

Line Oriented Flight Training (LOFT) allows you to:

- Create various realistic scenarios with high workload in normal work and with extreme situations, improve the performance of flight crew members in SOP implementation, train pilots in making competent and effective decisions, improve communication skills, relationships between flight crew members, evaluate and improve leadership skills , strengths, work on shortcomings in difficult and emergency situations.

- Identify potentially dangerous issues, contradictions, interpretations in airline documents (SOPs, RFPs, Standards, etc.) assess the effectiveness of flight crew training and weaknesses in training that require additional consideration.

A LOFT session should not be interrupted except in extreme circumstances. It is forbidden to change the position of the simulator and repeat any exercises. After the session is over, a thorough review of all aspects should be carried out. This is achieved through an initial self-debriefing by the crew members and then by the instructor). Once a year, during the LOFT, the flight is performed to the mountain airfield, according to the current scenario. CRM focuses on interpersonal communication, leadership and decision making in the cockpit.

CRM is a management system that allows the optimal use of all available resources - equipment, procedures and people and contributes to improving the safety and efficiency of aircraft management. CRM is not so much about the technical knowledge and skills needed to operate equipment, but the interpersonal skills and human abilities needed to manage resources within an organized system. In this context, human abilities are defined as the mental processes used to acquire and maintain situational awareness for problem solving and decision making.

2.2 Existing methods for assessing the quality of training of pilots for special cases of flight on the FFS.

At the entrance to the glide path changes the aerodynamic configuration of the aircraft, which is associated with the release of flaps and landing gear. When flying in director mode, this imposes additional actions on the pilot in the control of the aircraft. The operating load on the crew also increases. At simultaneous occurrence of failures or failures at crew members there can be the raised psychophysiological tension. Previously, this issue was considered in the area from the end of the fourth turn to landing on outdated aircraft [9]. Failures alone may not pose a threat, but in a state of stress, the crew may aggravate the situation. Since the change in the parameters of the aircraft in this area is ergodic and stationary, the gain (increase in the amplitude of the parameters) can be determined by autocorrelation functions.

Calculations are performed according to the formula:

$$K_i^{(j)} = \frac{1}{n-j+1}\sum_{i=1}^{n-j+1}\left(A_i - \frac{1}{n}\sum_{i=1}^{n}A_i\right)\left(A_{i+j-1} - \frac{1}{n}\sum_{i=1}^{n}A_i\right)$$

where n is the number of observations in the time series, Apar (amplitude of the parameter), j = 1, 2, 3,… L represents the delay of the argument at 0, 1, 2… (L - 1).

To perform spectral analysis of autocorrelation functions in Mathcad engineering mathematical software using the function A = cfft (K) for continuous functions.

The following Fourier integral formula can be used to calculate the spectrum from discrete values:

$$S_t = \sum_{i=1}^{N-1}\left(K_i \cdot e^{\frac{-i\cdot 2\pi\cdot i\cdot t}{N}}\right)$$

In addition, there are often hidden manifestations of increased human operator tension, which are manifested in the transition from a stationary random process to deterministic oscillations in the form of a sinusoid. Sometimes this is not accompanied by an increase in the amplitude of the parameters. This will be reflected in the fact that with the further action of other negative factors, the values of the amplitude of the parameters increase many times (Fig. 2.2.1).

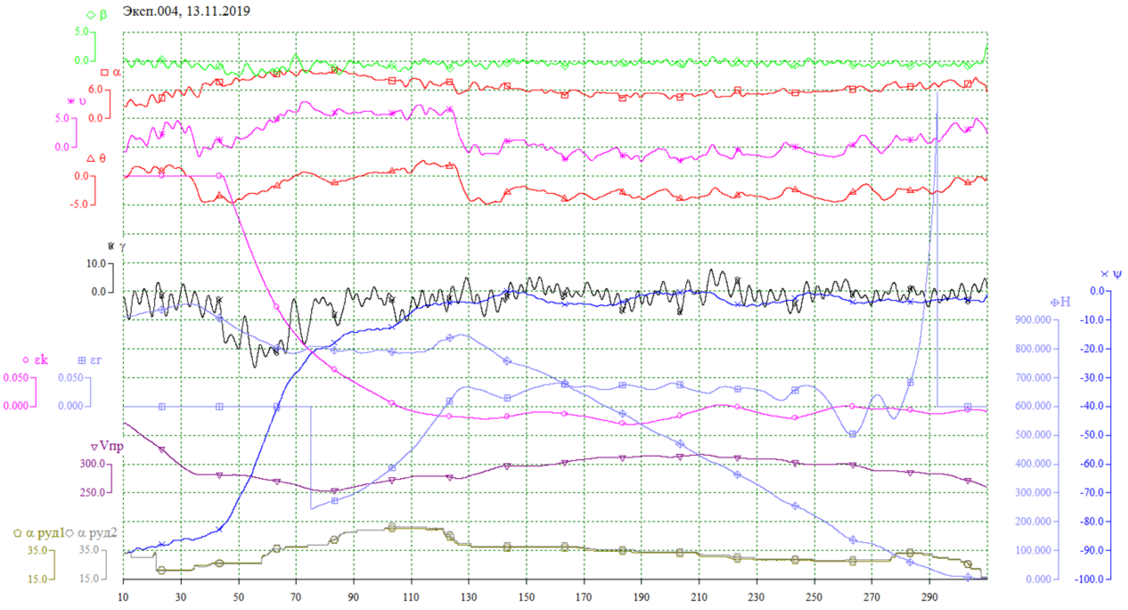


Fig. 2.1.1. "Flight" on FFS with failures of the first and third channels of fly-by-Wire and lack of control of the left aileron and interceptors on the left half-wing, where: Vpr - instrument speed (km / h); ψ - magnetic course (deg.): Θ - trajectory angle (deg.); ϒ - roll angle (deg.); υ - pitch angle (deg.); α - angle of attack (deg.); β - sliding angle (deg.); H - geometric altitude (m); εк - deviation from the course equal signal zone (RGM); εг - deviation from the glide path (RGM); α - position of the engine control lever (deg.)

According to the Neumann-Pearson test, the choice of the decision threshold V is based on the solution of the following equation for the case of no sinusoidal oscillations in the analyzed mixture:

$$\Pr\left(\frac{1}{\sigma^2}\sum_{i=1}^{N}S_i(x_i-\bar{x})-\frac{1}{2\sigma^2}\sum_{i=1}^{N}S_i^2\geq V\Big/H_0\right)=\alpha\,.$$

In this case, the decision threshold was determined by statistical modeling based on the Monte Carlo method. For a given sample size, the parameters of the detected sinusoidal oscillation and α = 0.01 we obtain V ≈ 0.

When training pilots on a complex simulator, it is necessary to practice exercises that involve the introduction into the flight situation of two or three failures of equipment on board, and determine the gain of each crew member. The failure block must include failures that do not affect the aerodynamics of the aircraft and the ability to control the aircraft.

Experience shows that uncertainty in assessing the situation in extreme flight conditions in 70-80% of cases leads to an increase in the amplitude of flight parameters due to increased tension of the pilots. Thus, the simulator should be used not only for learning specific actions, but also for anti-stress training. Let's consider one of the variants of the order of application of trend algorithms for the analysis of resistance of pilots to overlays of factors. Having the data of numerical or graphs of change of course (ψ), roll, pitch (ν) and vertical speed (Vy) from the end of the fourth turn to landing it is necessary to determine the distances from the extremes of these functions to zero. Calculate the difference between the extremums (without the module) of the change of each parameter. The results of the values of the amplitudes (A) are taken modulo. Identify the maximum and minimum A of each parameter. Calculate the half-periods (T) corresponding to the maximum and minimum values of each parameter.

$$\Delta A = \frac{A_{\max} - A_{\min}}{A_{\min}}; \Delta T = \frac{\mathrm{T}_{\max} - \mathrm{T}_{\min}}{\mathrm{T}_{\min}}.$$

After that make the general picture of polycanal change of parameters:

$$\Delta\Delta A_{\gamma,\psi,\vartheta} = \sqrt{\Delta A_{\gamma}^{2} + \Delta A_{\psi}^{2} + \Delta A_{\vartheta}^{2} + \Delta A_{V_y}^{2}};$$
$$\Delta\Delta \mathrm{T}_{\gamma,\psi,\vartheta} = \sqrt{\Delta \mathrm{T}_{\gamma}^{2} + \Delta \mathrm{T}_{\psi}^{2} + \Delta \mathrm{T}_{\vartheta}^{2} + \Delta \mathrm{T}_{V_y}^{2}}$$

Amplitudes can be measured and plotted on the coordinate axis when working with numbers in degrees, and when working with graphs - in conventional units, and periods - respectively in seconds and conventional units. Using trend algorithms, it is advisable to compare ($\Delta\Delta\delta$E.H.B) deviations of ailerons, rudder direction and altitude with ($\Delta\Delta A\gamma$, ψ, ϑ) changes in parameters:

$$\Delta\Delta\delta_{E,\mathrm{H},\mathrm{B}} = \sqrt{\Delta\delta_E^2 + \Delta\delta_{\mathrm{H}}^2 + \Delta\delta_{\mathrm{B}}^2}\ ;$$

$$\Delta\Delta A_{\gamma,\psi,\vartheta} = \sqrt{\Delta A_\gamma^2 + \Delta A_\psi^2 + \Delta A_\vartheta^2}\,.$$

For example, during the "chatter" the quality of piloting technique can be judged by the discrepancy, because with a strong chatter an experienced pilot does not allow strong deviations of parameters, although the consumption of rudder and ailerons is high. In the presence of objective control systems on the full flight simulator (FFS) can be ignored, because the "chatter" can be excluded from the instructor's console.

The algorithm and the program of training of counteraction with the minimum trend is expressed in "Methodical recommendations on increase of level of resistance of pilots to overlays of factors (for instructors and engineers)" №782 B90 for planes of that time. The degree of resistance of FN pilots can be judged by the difference between ΔΔAFN and flights without failures. The smaller the difference, the greater the degree of resistance, qualitative changes to quantify.

Erroneous and illogical actions of crew members during the flight, associated primarily with changes in mental processes due to the action of factor loads on them. Receiving spatial signals from the action of factor loads, with a sufficient number of them, the pilot can get into the area of reflected movements. The inability of pilots to actively counteract the factor load can lead to incorrect actions in the process of controlling the aircraft (confusion of levers, toggles, buttons, etc.). The counteraction to this phenomenon is the spatial delay of movements. And therefore it is very important in the training of the entire crew is to master the technique of spatial delay of movement in the control of the aircraft.

The problem of transition to dimensionless coefficients in the processing of oscillograms of flight information of the transition from instantaneous to interval estimation is successfully solved by using trend algorithms [7]. By trend we mean the steady changes in the process that are observed and give an opinion on its forecasting in the future. According to the processed statistics, the above method revealed a number of patterns that indicate the need for anti-stress training of most pilots [6]. Using the developed procedure for the application of trend algorithms, the occurrence of a negative phenomenon in pilots on An-26, Yak-40, Yak-42, Mi-8 helicopters and others was analyzed.

During the flight, pilots can not always avoid the appearance of erroneous actions. Moreover, as shown by the statistics collected on FFS-74, the duration of improper piloting of the aircraft increases with increasing number of simultaneously acting factors (in this case, failures).

The most characteristic errors in the technique of piloting under the influence of negative factors are: not maintaining the glide path and not maintaining the speed on the planning glide path, not maintaining the course, correcting it in the wrong direction, not maintaining the vertical speed, etc. Moreover, after the pilot begins to correct the error, then there is an increase in the dynamic stereotype of the amplitude and frequency, which is fixed by the means of flight registration. In the existing literature there is a diametrically opposite opinion - the actions of factor loads are not amplification, but the so-called "breaking" of the dynamic stereotype of action. Experiments on FFS and statistics do not confirm this. The discrepancy is especially visible on the waveforms on the parameter "roll angle". Verification of this provision is of great practical importance for the development of new training programs, as well as for the issuance of practical recommendations to the pilot to improve his piloting skills. The pilot begins to swing the plane around the desired parameter, which indicates the pilot's impact in the area of reflected movements, ie we see muscular (qualitative) or temporary (quantitative) quantitative rocking of the pilot, starting with spatial, derived from visual and purely tactile receptors. Moreover, visual sensations are objective, and muscular – subjective.

Erroneous and illogical actions in the process of flight, associated primarily with changes in mental processes, spatial signals from the action of factor loads. Receiving spatial signals from the action of factor loads with a sufficient number of them, the pilot can get into the zone of reflected movements, but spatial. The inability to actively counteract the factor load can lead to incorrect actions in flight engineers (confusion of levers, toggles, buttons, etc.). Hence, we see the importance of training the spatial delay of the entire crew. An important element in learning delays of this kind can be learning the flight logic. This is an important basis for his training, as well as choosing the only right solution when dealing with an unexpected stimulus. After performing alogisms, some pilots fall into the zone of temporary reflections, which shows their inability to delay temporary reflected movements.

Guided by the theory of counteraction Sechenov , who proved that all conscious movements are usually called arbitrary, but they can be repulsed. Strengthening of a dynamic stereotype without changes of "physiognomy" of movements is observed in the majority of crews at trainings.

We see from the calculation of the flight on the FFS that the integrated assessment of the degree of amplification of the dynamic stereotype when landing with the engine idle is greater than the integrated assessment when landing with not released end flaps. Ideally, the amplitude value should be compared when analyzing the flights of the same pilot without failures and with the entered failures. Thus, from this difference we can determine the amplitude gain that occurs in the pilot under the influence of factor loads, which are simulated on the FFS complex failures.

Preliminary calculations on the roll showed that the flight with a smaller overlay of factors on the pilots, differs from the maximum (engine failure, air horizon, failure of other systems). Studies have also been conducted on the introduction of three identical failures from the instructor's console, which do not affect the aerodynamics of the aircraft. The data show that in 80% of pilots this leads to amplitude amplification of the dynamic stereotype, increasing the flow of comments on pilot errors. Testing with the help of trend algorithms revealed that this phenomenon takes place in the form of polyparametric oscillation.

2.3 Influence of the human factor on the development of flight safety.

According to ICAO, about 80-90 percent of disasters are due to the human factor. Recently, the situation in civil aviation has not changed and this figure remains at the same level.

Consider ICAO's approaches to solving this problem. According to the registered data on the investigation of aviation events dating back to the 1940s, the human factor is connected with the majority of aviation events and incidents. Aviation accident investigation reports usually clearly state what happened and when, but in many cases they do not fully explain how and why such incidents occurred. Attempts to recognize, analyze and understand the problems underlying an event that led to disruptions in human work and thus to such an event are sometimes inconsistent.

When it is stated that the pilot did not follow the rules of operation, they mean that these rules are duly justified, and their implementation should provide the necessary safety. As a result, findings in investigation reports are often limited to phrases such as "pilot error", "did not notice and did not take action", "misuse of controls" or "did not follow standard operating rules (SOPs)".

This narrow approach is nothing more than one of the many obstacles to the effective study of human influence. In cases where events are combined and interact in a way that leads to a crash, the aviation accident investigation authority must ensure that all elements of a complex system have been investigated to understand why the event occurred.

Chapter 1 of Annex 13 of the ICAO defines an aviation event as: "an event involving the use of an aircraft occurring from the moment a person boarded with intent to fly, until all persons who were aboard an aircraft and in the course of which any person receives fatal or serious bodily injury, the aircraft is damaged or its structure is destroyed, or the aircraft goes missing or is found in a place where access it is absolutely impossible for him. "

There are many different approaches to help investigators identify the negative factors involved in aviation accidents and incidents, such as the Rison model.

In addition to Rizon's model, the task of data collection is facilitated by the conceptually new model "SHEL" [14-16]. This model was first developed by Professor E. Edwards in 1972, and later modified by F. Hawkins.

In this model, matching boundaries or non-matching block boundaries (interfaces) are just as important as the characteristics of the blocks themselves. Mismatches can be a source of human error

Fig.2.3.1. Model "SHEL",

where: S - settings (procedures, symbols, rules, etc.);

H - object (machine, equipment);

E - environment;

L - subject (person).

This model is an extended version of the human-machine-environment model in the ICAO Aviation Prevention Manual (Doc 9422) [2]. The SHEL model illustrates the importance of optimizing operator interaction and processing the information obtained. Each component of the SHEL model is one of the fundamental principles of human factor research.

The subject or human element is the core of the model, its most significant and flexible component. However, it has its drawbacks, most of which can be largely predictable.

The central human component does not act by itself, it clearly interacts with every other element. The boundaries of the human block are not simple and smooth, so the next blocks must be carefully fitted to it to prevent stress and ultimately disruptions (events). When considering issues related to the human factor, the line between what applies to it and what does not apply to it is often blurred. Data that initially did not seem to be relevant to the event may be extremely important once the relationship between specific events or factors has been established.

In order to establish the significance of the information obtained during the study, common sense is certainly needed. Information related to the aviation event can be obtained from a number of different sources. The main sources directly related to the human factor are data on equipment, documentation, recordings of voice and flight recorders and interviews with witnesses, direct monitoring of aviation personnel and simulation of the situation. Ancillary sources include aviation event databases, reference books, human resources experts and experts.

Having completed the collection of information on the human factor related to the event or incident, the researcher begins to analyze it. In most cases, researchers successfully analyze data that can be measured in relation to the human factor - such as muscular effort required to provide movement of the steering column, lighting needed to read the display, the required temperature and pressure, etc. Unfortunately, most important elements of the human factor are not easy to measure, and therefore not completely predictable.

As a result, a large amount of information about the human factor does not allow the researcher to draw unambiguous conclusions. Upon completion of the collection and analysis of relevant data, the person investigating the incident must prepare a report on the investigation. In accordance with the provisions of the ICAO Guidelines for the Prevention of

Aviation Accidents, precautionary measures against such incidents should be aimed at eliminating all hazards within the aviation system, regardless of their origin. Appendix 13 of the ICAO guidance pays considerable attention to such measures. Recommendation 7.1. says: "At any stage of the investigation of an aviation accident or incident, wherever they may occur, the competent authority investigating aviation events of the investigating State shall recommend to the relevant competent authorities, including the authorities of other States, any precautionary measures must be taken urgently to prevent similar events. "

Section 4 of the Safety Recommendations of the ICAO Accident Investigation Manual states: "This should include any safety recommendation prepared to prevent aviation accidents and indicate the corrective actions that follow from it, as appropriate. recommendations are included in the report as an integral part of it or are presented separately (depending on the procedures adopted in the States), it should be borne in mind that the ultimate goal of a truly effective investigation is to improve air safety. taking into account issues that have arisen as a result of the investigation, whether they are directly related to causal factors or have been caused by other factors identified during the investigation. "

The ICAO Safety Management Manual (DOC 9859 AN-474, Fourth Edition, 2018) [1] states that the “human factor” is directly influenced by the right working environment and a positive safety culture.

The culture of the aviation team is characterized by beliefs, values, traditions and rules that affect the relationship of aviation personnel. In order to effectively ensure the safety culture (SC) in the subjects of aviation activities, it is important for the leaders of the aviation team to identify a special area of their activities aimed at maintaining the SC.

"Safety culture" means professional and psychological training of aviation personnel, the main purpose of which is the internal need to comply with established standards of aviation safety, which ensures awareness of personal responsibility and self-control in the performance of work affecting flight safety. Understanding the components of the safety culture and the interactions between them is important for safety management.

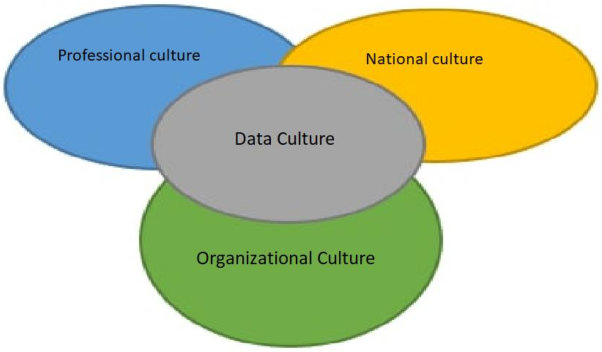


Fig.2.3.2. Components of flight safety culture

The three most important components of SC are organizational, professional and national culture. In addition, the culture of data provision is one of the main components these components. Figure 2.3.2 shows the components of safety culture.

The organizational culture of the aviation team includes a set of norms specified in the regulations on the organization and implementation (provision) of flights in the state aviation of Ukraine, as well as beliefs, principles that are an integral part of daily aviation system and are reflected in the actions of all aviation personnel who perform and provide flights. For the conditions of state aviation, these will be the basic principles that determine the procedure for organizing the implementation and provision of flights, taking into account the need to perform combat and special tasks.

Professional culture covers the peculiarities of norms of behavior within the units of the aviation team. It is a well-known fact that each flight support unit has its own typical behavior. The traditions and rules of the aeronautical engineering team differ from the behavior of pilots or flight crew members. These differences arise due to the peculiarities of professional selection of persons, their conditions of education and training, the nature of professional tasks, as well as the influence of colleagues and predecessors.

National culture distinguishes between the characteristics of individual nations, national priorities and values, the quality of legal systems, the method of distribution of powers and responsibilities. distance. The political and economic situation in the country, national traditions, religious beliefs also affect the attitude of aviation personnel to the performance of their duties, which directly affects the effectiveness of flight safety.

The culture of data that may threaten flight safety is to build an effective system of informing the management of aviation entities about existing and future risks (threats) with the sole purpose of improving safety. The level of data culture is directly related with the depth of acceptance of responsibility by aviation personnel for the risks hidden during the aviation system. This component of the components of SC directly depends on organizational, professional and national cultures and in civil aviation is the main criterion when evaluating the effectiveness of the system providing SC. The success of the data submission information system depends on the continuity and openness of the flow of information from aviation personnel.

2.3.1. Processing flight parameters. Their history and development.

The aeronautical industry’s efforts to design recording devices that could sustain accidental damage, such as impact and fire, date to the beginning of commercial aviation. It was only in 1958 that aviation authorities began imposing minimum specifications for flight recorders to aid technical investigations.

Boeing 707’s, DC8’s and Caravelles were the first jet engine aircraft to be equipped with FDRs in the early sixties. These recorders consisted of a mechanical stylus engraving a metal foil. For metal foil FDRs, the parameters are processed internally with data coming in directly from basic aircraft sensors, such as accelerometers and pitot tubes. At about the same time, a similar technology consisted of replacing the sheet of metal with a photographic film and the mechanical stylus with light beams. That was the photographic film FDR. Both types of FDRs could only monitor a limited number of important parameters, usually 5 or 6, such as magnetic heading and airspeed.

Metal foil and photographic film FDRs started to fall behind in relation to investigation needs in 1965. With the introduction of magnetic tape-based recorders, it became possible to not only record conversations but also to progressively increase the number of parameters monitored by FDRs.

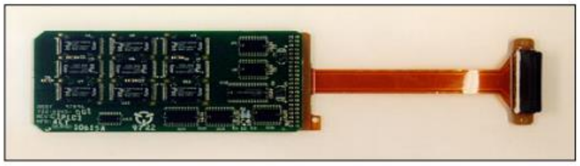
With the new magnetic FDRs, parameters were no longer recorded in a single stream. Instead, they were first sampled, digitalized and multiplexed inside a 1- second long frame. Then, this digital frame was recorded on a magnetic tape using simple signals to code 0’s and 1’s. Hence the name Digital Flight Data Recorder (DFDR) [5].

Fig. 2.3.1. Inside a magnetic recoder

As the need for more parameters grew and as new digital technology appeared, it became inadequate to have FDRs compute parameters internally based on data received from sensors. Flight data acquisition devices began to be designed to collect all parameters before being recorded. These devices include the Flight Data Acquisition Unit (FDAU), Flight Data Interface Unit (FDIU) or Flight Data Acquisition Card (FDAC). They order data and then send it to FDRs, whose function is then limited to data recording. Note: Aircraft operators can modify FDAU programming. It is important to note that mainly large aircraft in the public transport category are equipped with data acquisition units. For smaller aircraft, the data acquisition function is still often performed by FDRs.

With the evolution of digital technologies, solid-state memory cards replaced magnetic tapes in FDRs around 1985. Recordings on these new Solid State Flight Data Recorders (SSFDR) have far better restitution reliability than on the magnetic FDRs.

As memory cards got smaller, the number of recorded parameters went up to several hundred, sampling frequencies increased and recording times of some models rose to 50 hours or more. Sound recorders also benefited from this technological evolution, with not only the possibility of recording sound digitally, but also with a recording time that was extended to 2 hours as opposed to half an hour for magnetic tape-based CVRs.



Memory Card on an SSFDR

Fig.2.3.2. Memory Card on an SSFDR

The introduction of data acquisition units has also benefited what is commonly called “flight data monitoring”. FDRs were the only devices recording data and that data was only used after an accident. Now, with data acquisition units, data is also directed to other types of recorders. These recorders are not protected. The recording media can be a tape, an optical magnetic disc. The recording media is designed to be removed and replaced quickly. The access to the recording media is located either in the cockpit or in the electronics bay. Quick Access Recorders (QAR’s) usually record exactly the same data as FDRs. Onboard an aircraft, the data acquisition unit feeds both the FDR and the QAR. The most recent QARs also have input ports compatible with the standard aircraft buses (ARINC 429) and can therefore receive additional data. Direct Access Recorders (DARs) receive data from Data Management Units (DMUs) and can be programmed not only to select which parameters to record and with which sampling frequency, but also to select the recording mode: periodic recording or recording triggered by events such as a parameter passing over a pre-determined threshold. These recorders are used for maintenance, research or flight data monitoring purposes [5].

Chapter 3: Development of a flight parameters processing system and recommendations for aircraft crew training.

In this chapter, we will analyze aircraft flight processing algorithms based on FFS flight simulations with certain failures, demonstrate possible improvements in flight safety processing for flight safety, and suggest possible upgrades to crew training systems for special flight situations.

All the data obtained in this chapter may benefit the aviation industry and the development of flight safety in the future.

3.1 Improving the processing of flight parameters to ensure flight safety.

To enhance the processing of flight parameters, it’s possible to improve the buses. Let’s provide it with an example of the most widespread ARINC 717.

Memory Layout In ARINC 717, data are stored in 12 bit words. However, CPUs can only handle word sizes that are a power of two. The shortest adressable unit is the byte (8 bit). Recorded 12 bit data can thus fit easily into a 16 bit unit. However, in our previous method, data were indexed at the bit level. Bits were stored as bytes, allocating 7/8ths of unused memory. Encoded values where then indexed as individual bits, and assembled in a linear combination with powers of two. Instead, we now handle “words” as the smallest unit, reducing memory consumption by a factor of at least six and making the whole process more robust. While reducing peak memory, we could also reduce memory bandwidth alongside, speeding up the process. With the reduced memory footprint, a single machine can now also decode multiple flights in parallel. We have seen from experience, that recorded data might already come stored in a 16 bit word layout [4].

In other files we have seen a packed dataframe where no padding bits are inserted. We can read these “12 bit packed files” byte-by-byte, store bytes into 16 bit words, and regroup every three bytes into two 16 bit words of 12 bit data. Using a scripting language that supports vectorization, this operation is more efficient than our previous approach of storing and expanding individual bits as bytes.

Once we have data in 16 bit words, we reshape and sort data into a 4D data structure as was done in. In the latest version, writing the algorithm out in Matlab, pure vectorized commands are used, speeding up the process. In general, for execution performance, our main goal was to minimize the occurrence of explicit loops and branching instructions. The 4D data structure is used to index parameter parts easily.

When indexing into this data structure, the order of these dimensions is important and depends on which language is used. In Python with numpy, values are stored in a column-major layout. That implies that the “fastest-changing,” or innermost dimension (i.e. “ word”) is last and “superframe” first. In Matlab, matrix values are row-major. Here, “word” is the first dimension. If done right, one can linearily index all dimensions in a single instruction.

Data can be corrupted on a subframe level. With each subframe having a distinct synchronization word, we can keep track if there are missing, corrupted or duplicate subframes. When we bring data to its 4D shape, we first determine how many valid subframes there are and into how many frames they aggregate. We then allocate just enough uninitialized memory to store everything, including all missing subframes. Then, we assign only the valid subframes, according to their sync-words and leave corrupted sections in their unknown state. Instead, we track an “integrity mask” alongside, that marks which subframes, frames and superframes have been assigned successfully. These again are only vectorized operations.

In the initial design for the tool , we used a relational database server to store the dataframe layouts. There are tables for each dataframe, for each parameter and for each parameter part location (because of multipart parameters). Since the overall structure is very much tree-like, we decided to abandon this relational form of dataframe description in favor of hierarchical markup languages such as XML or YAML. These text-based dataframe descriptor documents can also be easily stored in our version control system. We load the dataframe document into an object-oriented data structure, where each object has many sensible default properties already. On the top level, the user specifies a Dataframe object, that defines the overall file structure through WordsPerSecond, the memory layout and a list of Parameter definitions. From experience most parameters start out as unsigned 12 bit scaled values recorded at 1 Hz. In the dataframe document, you only have to specify any deviations from the default. You can use the properties given here, e.g. Bits which is a 12 bit bitmask, or use the dependent accessor properties that simplify some config tasks. From experience again, dataframe documents typically specify a least and most significant bit for the recorded range. However, our code runs faster using bit masking logic, so the single source of thruth is Bits. LSB and MSB are calculated on-the-fly when you build the dataframe structure. The same goes for the Polynomial configuration. Raw bit values are extracted from the data stream first, then typically linearily scaled and offset. We have seen dataframes however, that specify a nonlinear polynomial scaling on the raw value.

Dataframe layouts can be loaded either from YAML, XML, INI or directly from code. We are also able to estimate the dataframe for some typical parameters (position, altitude, ground speed, air speed, track, vertical acceleration, vertical speed) from an arbitrary ARINC 717 file.

The process of estimating the dataframe is iterative, where partial solutions contribute to the estimation of other file features:

1) First, we estimate the block structure and encoding of the given ARINC 717 file. We can do this by quickly brute-forcing combinations of WordSize and WordsPerSecond on a small subset of the file. Knowing the 6 structure, we can already bring the file into 3D structure.

2) We can then quickly brute-force the detection of the FrameCounter, because we can expect a value at the same subframe / frame position to increment every 16th frame. With the frame counter detected, we can bring data into 4D shape.

3) We apply a clustering method on the data points from the previous step. If a parameter has a recording frequency larger than 1/64 Hz, we can identify point clusters.

4) Knowing about the probable repetition patterns, we can write a temporary dataframe to extract consistent parameters, though we do not know the contents of any parameter yet.

5) Using the structure as a basis, we use pattern detection from a pre-trained algorithm to identify basic parameters such as ground speed, air speed, latitude, longitude and pitch angle.
6) In a second (and third) pass, we can use successfully decoded parameters to create models for others, e.g. track from position or accelerations from speed.
7) We can also identify the jump bits (if existent) that complement a wrapped 12 bit maxed out parameter range if the parameter was originally split across two words.

8) We can finally fix the scaling of the detected parameters under the assumption that angular parameters are encoded in fractions of 360 degrees and others typically in powers of two. For latitude / longitude in particular, we use a global database of airport locations to find the best match of scaling factors so that the route is anchored at existing airports.

From experience, some parameters such as GPS latitude and longitude are recorded with high precision requiring more than 4096 distinct values (12 bit). Those parameters are typically split into a coarse and fine part, as shown before in the previous section. We have seen, that in some dataframes the coarse part has a reduced sampling rate (e.g. 0.25 Hz) to save memory, since it does not contribute to the overall precision (fine part with 1 Hz). If we multiply both the coarse and fine parts according to their dataframe specification, we can identify outliers.

We could now proceed applying outlier detection and replacing these values with not-a-number. However, since we know that these are caused by a slight misalingment of both parts, we can shift individual offending data points in the coarse part in time, so that the reset in the fine signal corresponds precisely to the jumps in the coarse signal.

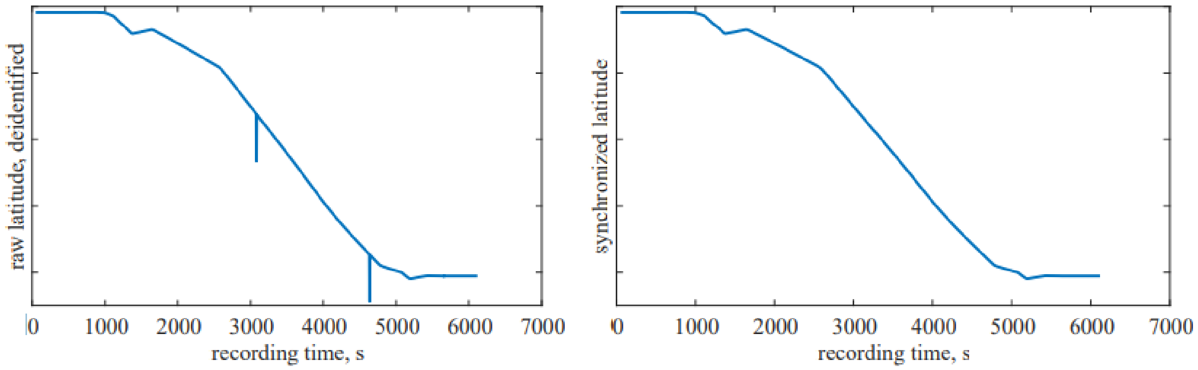


Fig. 3.1.1 left: sum of misaligned parameter parts leading to outliers, right: synchronizing the alignment of parameter parts resolves the outliers.

3.2 Algorithms for processing aircraft flight parameters.

The basis of the algorithms for processing the flight parameters of the aircraft is a system for estimating the deviation from the normal distribution according to the criterion of agreement “*xi*-квадрат” – χ^2 .

Based on the simulation of flights with certain deviations on FFS from the work of Hryshchenko Yurii, Zaliskyi Maksym, Pavlova Svitlana, Solomentsev Oleksandr, Fursenko Tetiana. Data Processing in the Pilots` Training Process on the Integrated Aircraft Simulator. Electrical, Control and Communication Engineering. 2021, Riga, RTU, 2021 [8] we can calculate the distribution χ^2 , the probability p that due to purely random reasons the degree of discrepancy will be not less than we actually observe (in these tests) and draw conclusions about the plausibility of the hypothesis.

Firstly, let’s calculate the data for the first and third flights.

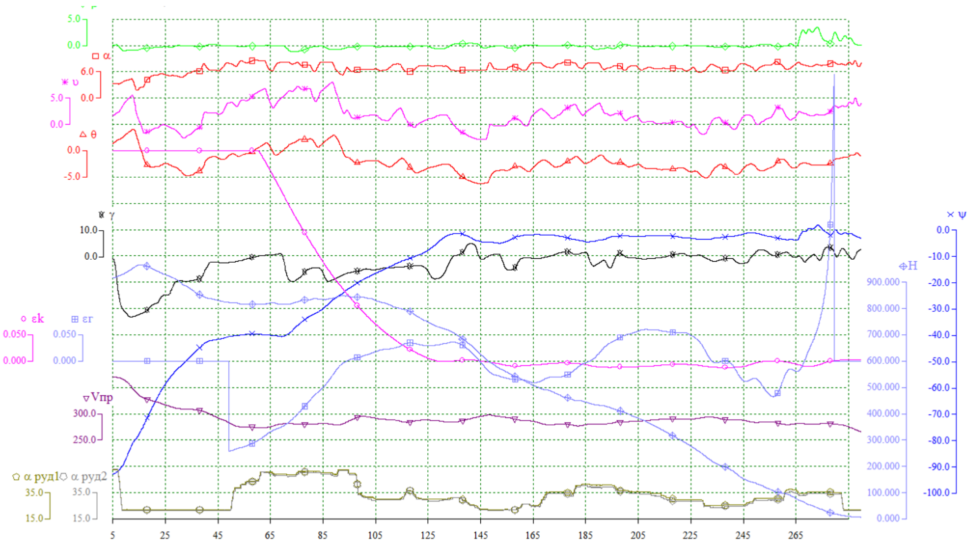


Fig. 3.2.1. Flight 1. Regular flight of the An-158 aircraft

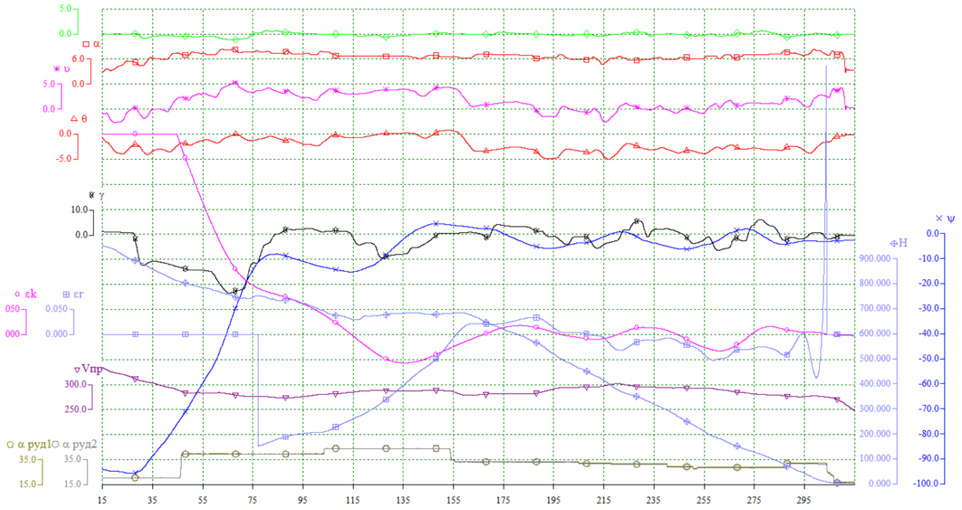


Fig. 3.2.2. Flight 3. Asymmetry of the flaps, the flap of the left wing

Data of 1 nd 3 flights

$$\gamma := \begin{pmatrix} -9 & 5 & -2 & 0.5 & 5 & 2 & 0.5 & 2 & -4 & -2 & -5 & 1 & -2 & 1 & 0 & -2 & -1 & -3 & 2.5 & -0.5 & 0 & -2 & 0 & -1 & 4 & 0 & -8 \\ -6 & 0 & -2 & 4 & 1 & -1 & -4 & -1 & -6 & -3 & 2 & 5 & -1 & 3 & -4 & -1 & -6 & -2-3 & 6 & 3 & -3 & -2 & 0.5 & -3 & -0.5 & -0.5 & 0 \end{pmatrix}$$

$$n := \mathrm{hist}(7,\gamma) = \begin{pmatrix} 2 \\ 5 \\ 7 \\ 16 \\ 12 \\ 6 \\ 6 \end{pmatrix} \qquad fg := \mathrm{histogram}(7,\gamma) = \begin{pmatrix} -7.929 & 2 \\ -5.786 & 5 \\ -3.643 & 7 \\ -1.5 & 16 \\ 0.643 & 12 \\ 2.786 & 6 \\ 4.929 & 6 \end{pmatrix}$$

$K := 7 \qquad \Delta\gamma := 2.143 \qquad N := 54 \qquad k := 0..6 \qquad q := \min(\gamma) = -9$

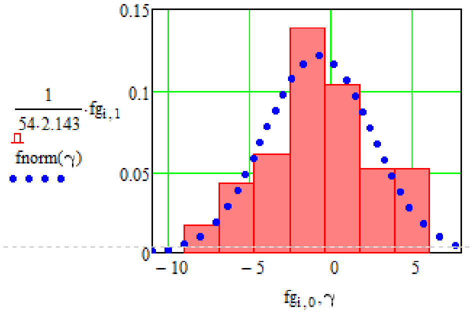
$\mathrm{mean}(\gamma) = -0.787 \qquad \mathrm{var}(\gamma) = 10.58 \qquad \sigma := \sqrt{\mathrm{var}(\gamma)} = 3.253 \qquad d := \mathrm{var}(\gamma) = 10.58$

$\mu := -0.787 \qquad c := \dfrac{1}{\mathrm{mean}(\gamma)} = -1.271 \qquad \gamma := -11..11 \qquad \nu := \dfrac{\sigma}{\mu} = -4.133$

$int_k := -9 + \Delta\gamma \cdot k$

$$int = \begin{pmatrix} -9 \\ -6.857 \\ -4.714 \\ -2.571 \\ -0.428 \\ 1.715 \\ 3.858 \end{pmatrix} \qquad k = \begin{array}{|c|}\hline 0 \\ \hline 1 \\ \hline 2 \\ \hline 3 \\ \hline 4 \\ \hline 5 \\ \hline 6 \\ \hline \end{array}$$

$$fnorm(\gamma) := \frac{1}{\sigma\sqrt{2\cdot\pi}} \cdot \exp\left[-\frac{(\mu-\gamma)^2}{2\cdot\sigma^2}\right]$$



$$fnorm(\gamma) := \frac{1}{\sigma\sqrt{2\cdot\pi}} \cdot \exp\left[-\frac{(\mu-\gamma)^2}{2\cdot\sigma^2}\right]$$

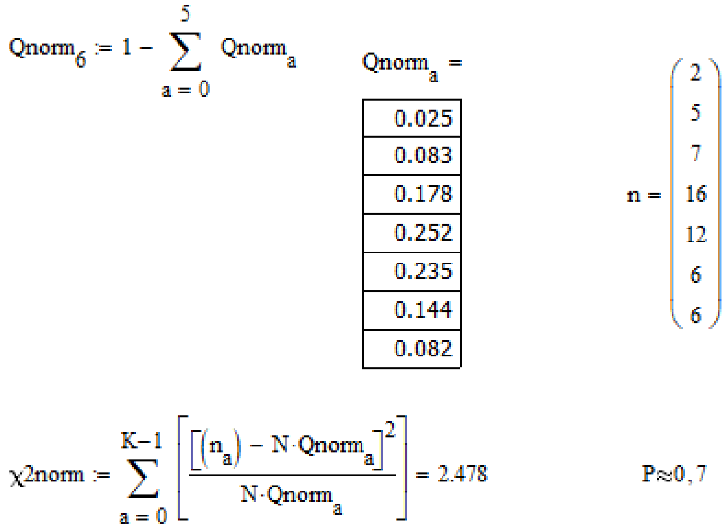
Analysis of consent Norm-model

The theoretical probability of failure in the k-th interval Δt

$N := 54 \qquad a := 0..6 \qquad K := 7 \qquad k := -9 + K - 1$

$\gamma := -9..6 \qquad r := K - 3 = 4 \qquad \Sigma n := 54$

$$Qnorm_a := \int_{int_a}^{int_a+\Delta\gamma} fnorm(\gamma)\, d\gamma$$



$$Qnorm_6 := 1 - \sum_{a=0}^{5} Qnorm_a$$

$Qnorm_a =$
0.025
0.083
0.178
0.252
0.235
0.144
0.082

$$n = \begin{pmatrix} 2 \\ 5 \\ 7 \\ 16 \\ 12 \\ 6 \\ 6 \end{pmatrix}$$

$$\chi2norm := \sum_{a=0}^{K-1} \left[\frac{\left[(n_a) - N \cdot Qnorm_a \right]^2}{N \cdot Qnorm_a} \right] = 2.478 \qquad P \approx 0,7$$

According to calculations, the criterion of agreement “*xi*-квадрат” – χ^2 is 2.478, and the probability p = 0.7. Since, $p \geq 0,10$, the hypothesis is considered plausible (at least not inconsistent with the studied data).

And now you need to calculate the same parameters for 10 flights.

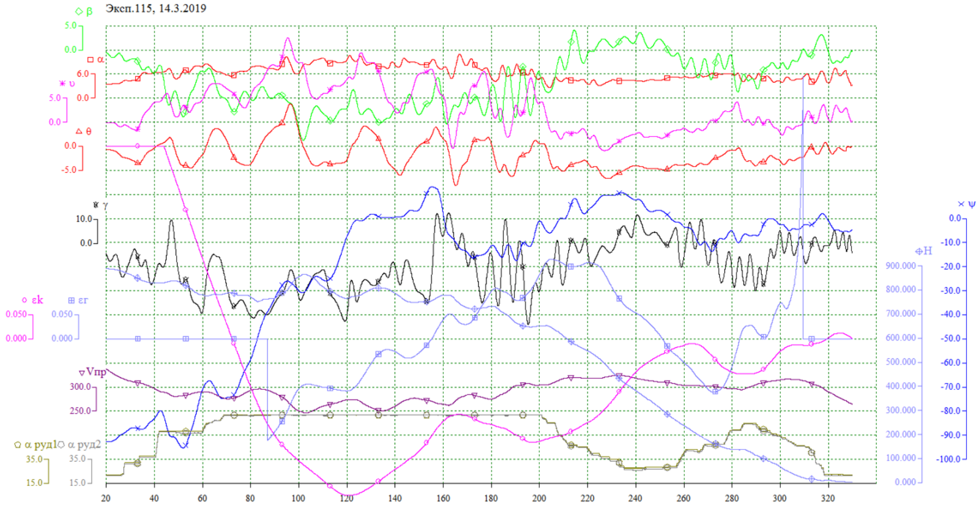


Fig.3.2.3. Flight 10. Complete failure of fly-by-Wire (backup control without damping) + Failure of the second (right) engine

10 flight, 210 sec

$$\gamma := \begin{pmatrix} -32 & -15 & -25 & -15 & -18 & -13 & -14 & -8 & -17 & -7 & -24 & 12 & 3 & 12 & -3 & 4 & -10 \\ -4 & -25 & -4 & -25 & 10 & -23 & 0 & -33 & -17 & -20 & -9 & -14 & 1 & -18 & 1 & -4 & 2 \\ -10 & -2 & -3 & 7 & 12 & 4 & -1 & 7 & -10 & 9 & -2 & 10 & -10 & 1 & -17 & -3 & -19 \\ -6 & -17 & -5 & -20 & -10 & -18 & -3 & -5 & 5 & -4 & 4 & -5 & 3 & -9 & 2 & -3 & 5 \\ -3 & 4 & -3 & 3 & -7 & -13 & -2 & -4 & 6 & 1 & 6 & 3 & 9 & -3 & 1 & -7 & 0 \\ -11 & -6 & -5 & -9 & -3 & -4 & 6 & 4 & 9 & 6 & 12 & -2 & 3 & 13.5 & -4 & -9 & -2 \\ -5 & 2 & 0 & 8 & 0 & 5 & 2 & 5 & -3 & 0 & -5 & -4 & -7 & 0 & -13 & -6 & -13 \\ 4 & 3 & 4 & 2 & 1 & 3 & 0 & 3 & 3 & 2 & -3 & -2 & -3 & 1 & 3 & 0 & 3 \end{pmatrix}$$

$$\gamma := \begin{pmatrix} 32 & 15 & 25 & 15 & 18 & 13 & 14 & 8 & 17 & 7 & 24 & -12 & -3 & -12 & 3 & -4 & 10 \\ 4 & 25 & 4 & 25 & -10 & 23 & 0 & 33 & 17 & 20 & 9 & 14 & -1 & 18 & -1 & 4 & -2 \\ 10 & 2 & 3 & -7 & -12 & -4 & 1 & -7 & 10 & -9 & 2 & -10 & 10 & -1 & 17 & 3 & 19 \\ 6 & 17 & 5 & 20 & 10 & 18 & 3 & 5 & -5 & 4 & -4 & 5 & -3 & 9 & -2 & 3 & -5 \\ 3 & -4 & 3 & -3 & 7 & 13 & 2 & 4 & -6 & -1 & -6 & -3 & -9 & 3 & -1 & 7 & 0 \\ 11 & 6 & 5 & 9 & 3 & 4 & -6 & -4 & -9 & -6 & -12 & 2 & -3 & -13.5 & 4 & 9 & 2 \\ 5 & -2 & 0 & -8 & 0 & -5 & -2 & -5 & 3 & 0 & 5 & 4 & 7 & 0 & 13 & 6 & 13 \\ -4 & -3 & -4 & -2 & -1 & -3 & 0 & -3 & -3 & -2 & 3 & 2 & 3 & -1 & -3 & 0 & -3 \end{pmatrix}$$

$$n := \mathrm{hist}(8, \gamma) = \begin{pmatrix} 11 \\ 34 \\ 34 \\ 26 \\ 14 \\ 10 \\ 5 \\ 2 \end{pmatrix} \qquad fg := \mathrm{histogram}(7, \gamma) = \begin{pmatrix} -10.179 & 13 \\ -3.536 & 39 \\ 3.107 & 44 \\ 9.75 & 19 \\ 16.393 & 12 \\ 23.036 & 7 \\ 29.679 & 2 \end{pmatrix}$$

$30.094 - 24.281 = 5.813$

$29.679 - 23.036 = 6.643$

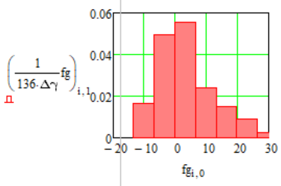
$d := \mathrm{var}(\gamma) = 86.324$ $\sigma := \sqrt{\mathrm{var}(\gamma)} = 9.291$ $q := \min(\gamma) = -13.5$ $q1 := \max(\gamma) = 33$ $\mathrm{skew}(\gamma) = 0.808$

$K := 8$ $\mathrm{mean}(\gamma) = 3.57$ $\mathrm{var}(\gamma) = 86.324$ $c := \frac{1}{\mathrm{mean}(\gamma)} = 0.28$ $Cv := \frac{\mathrm{stdev}(\gamma)}{(\mathrm{mean}(\gamma))} = 2.603$ $b := 1.75$ $a1 := \frac{\mathrm{stdev}(\gamma)}{0.52} = 17.867$

$\gamma := -13.5 .. 33$ $k := 0 .. K - 1$ $N := 136$ $\Delta\gamma := \frac{q1 - q}{K} = 5.813$

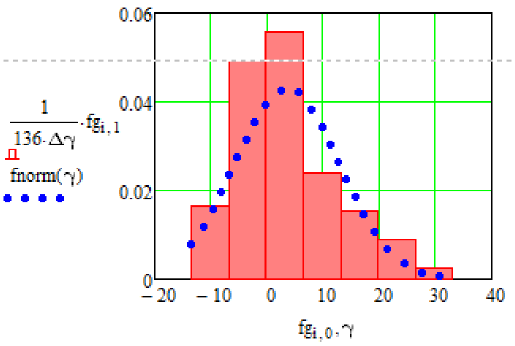
$\mu := 3.57$ $\nu := \frac{\sigma}{\mu} = 2.603$ $\mathrm{int}_k := -13.5 + \Delta\gamma \cdot k$

$$n = \begin{pmatrix} 11 \\ 34 \\ 34 \\ 26 \\ 14 \\ 10 \\ 5 \\ 2 \end{pmatrix}$$



Normal

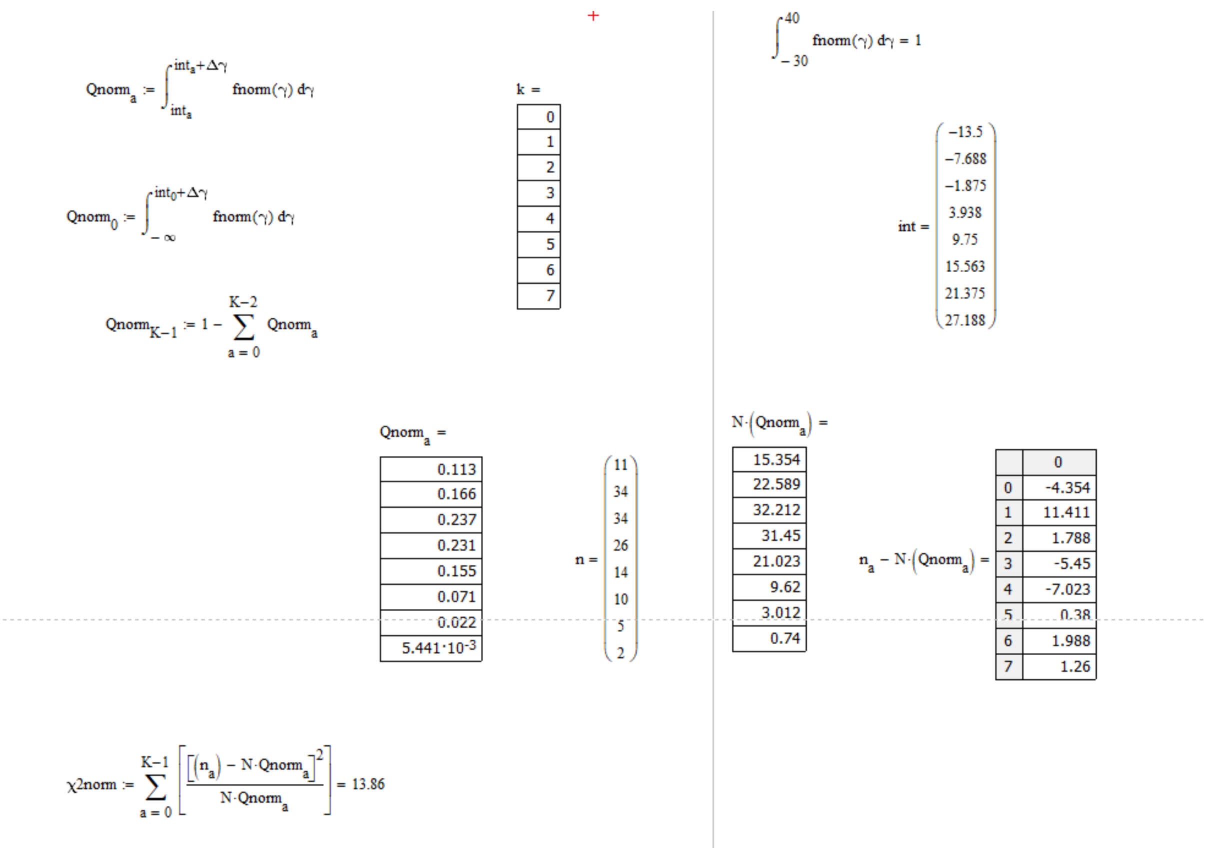
$$\mathrm{fnorm}(\gamma) := \frac{1}{\sigma\sqrt{2 \cdot \pi}} \cdot \exp\left[-\frac{(\mu - \gamma)^2}{2 \cdot \sigma^2}\right]$$



Analysis of consent Norm-model

The theoretical probability of failure in the k-th interval Δt

$a := 0 .. K - 1$



$$Qnorm_a := \int_{int_a}^{int_a+\Delta\gamma} fnorm(\gamma)\,d\gamma$$

$$Qnorm_0 := \int_{-\infty}^{int_0+\Delta\gamma} fnorm(\gamma)\,d\gamma$$

$$Qnorm_{K-1} := 1 - \sum_{a=0}^{K-2} Qnorm_a$$

k =

0
1
2
3
4
5
6
7

$Qnorm_a =$

0.113
0.166
0.237
0.231
0.155
0.071
0.022
$5.441\cdot10^{-3}$

$$n = \begin{pmatrix} 11 \\ 34 \\ 34 \\ 26 \\ 14 \\ 10 \\ 5 \\ 2 \end{pmatrix}$$

$$\chi 2norm := \sum_{a=0}^{K-1} \left[\frac{\left[\left(n_a\right) - N\cdot Qnorm_a\right]^2}{N\cdot Qnorm_a} \right] = 13.86$$

$$\int_{-30}^{40} fnorm(\gamma)\,d\gamma = 1$$

$$int = \begin{pmatrix} -13.5 \\ -7.688 \\ -1.875 \\ 3.938 \\ 9.75 \\ 15.563 \\ 21.375 \\ 27.188 \end{pmatrix}$$

$N\cdot\left(Qnorm_a\right) =$

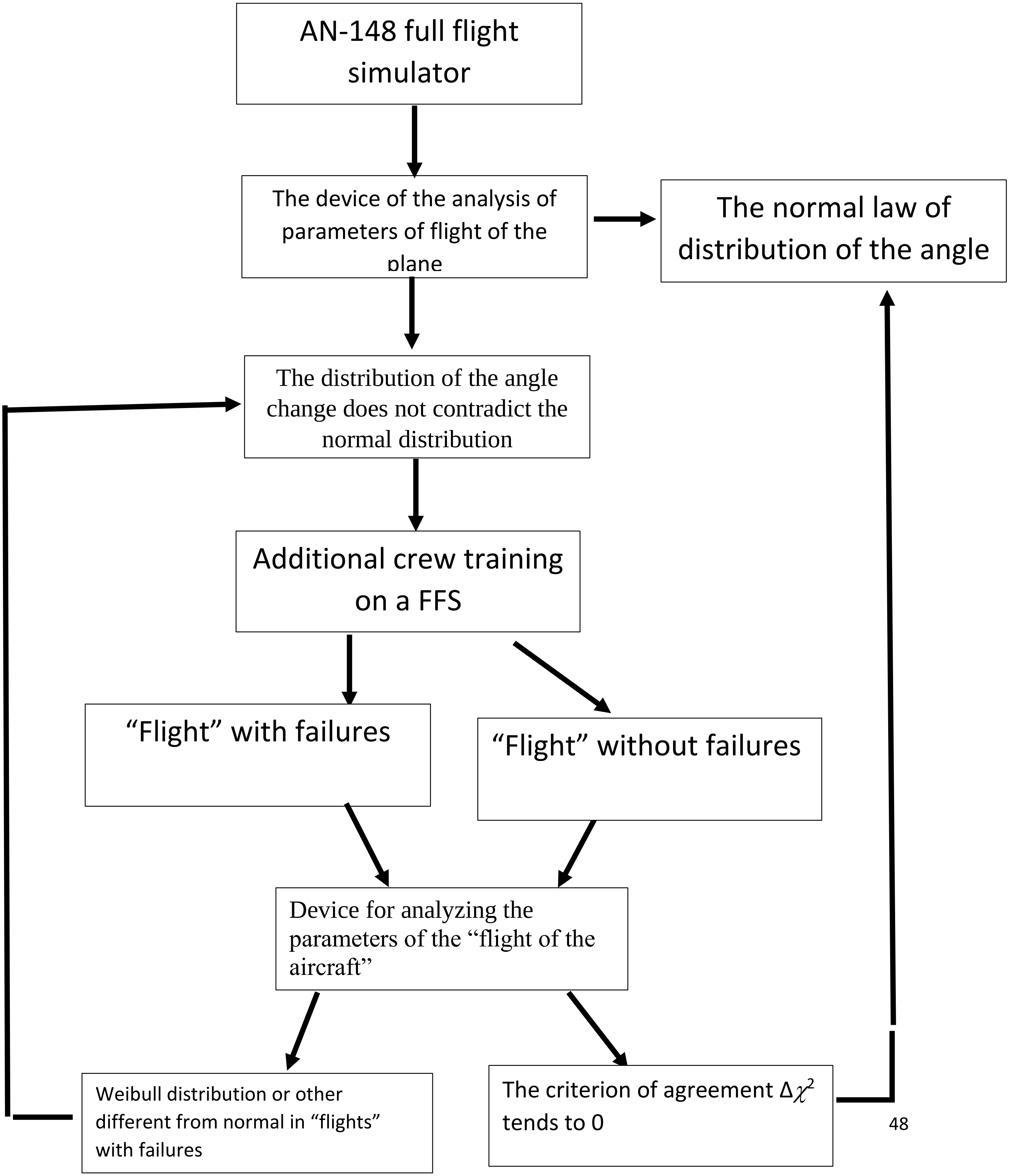
15.354
22.589
32.212
31.45
21.023
9.62
3.012
0.74

$n_a - N\cdot\left(Qnorm_a\right) =$

	0
0	-4.354
1	11.411
2	1.788
3	-5.45
4	-7.023
5	0.38
6	1.988
7	1.26

According to the calculations of 10 flights, the criterion of agreement "*xi*-квадрат" – χ^2 дорівнює 13.86, is 13.86, and the probability p is close to 0.02. Since $p \leq$ 0,10, it is recommended to test the experiment (if possible) and in case noticeable discrepancies reappear, try to find a more suitable model for failure to describe statistics.

After these calculations, we can conclude that with simple failures enough normal distribution, failures should be trained to normal, failures should not be more than three, they should not affect the aerodynamics of the aircraft, duplicates should work and failures should not affect the system management.


AN-148 full flight simulator
The device of the analysis of parameters of flight of the plane
The normal law of distribution of the angle
The distribution of the angle change does not contradict the normal distribution
Additional crew training on a FFS
"Flight" with failures
"Flight" without failures
Device for analyzing the parameters of the "flight of the aircraft"
Weibull distribution or other different from normal in "flights" with failures
The criterion of agreement $\Delta\chi^2$ tends to 0

When processing a large amount of data, it was found that with positive flight results, the distribution of the bank angle change does not contradict the normal distribution, and with negative results, it does not contradict the Weibull distribution.

3.3 Modernization of the aircraft crew training system in the conditions of a special flight case.

The air transport industry plays an important role in global activity and development. Aviation takes great responsibility for the safety, reliability, efficiency and environmental friendliness of transport at the global, regional and national levels. The modern aviation industry produces very reliable equipment. Climbing aboard the aircraft, the pilot becomes part of the system "man-machine-environment" and for a successful flight, he is no less important than the control surface. Complex fleeting processes inherent in aviation have a large number of variable parameters that need to be controlled and taken into account in the management of the aircraft, and which require pilots to receive and process information that exceeds their physiological and physical capabilities. Ignoring the pilot during pre-flight training is as pointless as not checking the control surfaces or any other vital parts of the aircraft. But the pilot is responsible for determining his airworthiness before he enters the cockpit to perform the flight.

As a result of adverse external factors and degrading internal processes, a special flight situation can occur, which has four types according to the degree of danger: complicated flight conditions, difficult situation, emergency situation, catastrophic situation [10]. The emergence of a special situation in flight begins with the influence of a single adverse factor, and then as a result of their combination and accumulation, it leads to a decrease in flight safety.

The Air Accident Investigation Commission never covers in the final report only one factor that caused a special situation, so we can say that along with technical and anthropogenic factors is the concept of factor overlays. According to the Airworthiness Standards (AS) of transport category aircraft difficult situations are characterized by:

1. Significant deterioration of performance and / or going beyond one or more parameters, but without reaching the limit;

2. Decreased ability of the crew to cope with adverse conditions, both with increasing workload and due to conditions that reduce the effectiveness of the crew.

Prevention of the transition from a difficult situation to an emergency or catastrophic in the course of the flight is provided only by the correct and timely actions of the crew members in accordance with the flight operations manual of the aircraft. In addition, pilots must immediately change their flight plan, profile and mode, but this should not require excessive effort or unusual piloting techniques. The complexity of flight tasks due to many different initial conditions, management criteria, statistical nature of external factors, but at the same time the requirement of unconditional performance of these tasks does not allow to create a system without human participation.

Despite the frequent mistakes of the pilot during difficult flight modes and the high cost of his mistakes, it is still impossible in such modes to completely eliminate him from the control process. An analysis of aviation events over the past 30 years shows that one in three of the four accidents is the result of many functional errors made by qualified aircraft crew members. There are many reasons: starting from technical malfunctions and shortcomings of structural equipment and continuing with insufficient training of aviation personnel, etc. In many cases, an accident or catastrophe could be avoided, but due to many factors it is impossible. Particular attention in the analysis of air accidents can be paid to the human factor. Having pushed to the background the psychological and physiological characteristics of the crew members that arise during a special situation, we highlight the flight operations that must be performed by the crew (Table 3.3.1).

Table 3.3.1

Execution of procedures

Procedure performed:		Procedure not performed:	
1	Incorrect	1	Due to lack of notification
2	False	2	In the presence of a notification
3	Inattentive	3	Due to inattention
4	With a delay	4	Just as the pilots forgot to do it
5	Correct, with observance of airworthiness standards, but not in the place of breakdown	5	As pilots neglected necessity of its performance
6	Delayed	6	As it is not written in airworthiness standards
7	With exceeding the tolerances of airworthiness standards	7	Due to ignorance of the design features of the aircraft

Having identified several plane crashes, you can classify them using Table 3.3.1.

After analyzing the emergency landing of the Tu-204 in Moscow (2010), we can identify the following crew errors:

1. The procedure was not performed because the pilots neglected the need to perform it: the pilots did not notify the controller of the autopilot's refusal.

2. Poor training: insufficient preparation for landing at the extreme meteorological minimum.

3. Unsatisfactory relations between crew members.

4. The procedure was not performed because the pilots forgot to perform it: departure to another airport, departure to the second circle.

5. Technical malfunctions: failure of the computer flight control system.

Fig. 3.3.1. Photo of the consequences of the emergency landing of the Tu-204 in Moscow (2010)

Another striking example of the errors in the procedures that led to the accident was the Boeing 737 crash near Pucallpa (2005). The following problems occurred during this flight: 1. The procedure was performed incorrectly: the crew decided to continue the visit to the airport in a storm.

2. The procedure was performed incorrectly: the crew decided not to avoid the storm, not to go to another airport.

3. Poor maintenance of the aircraft: loss of visibility due to broken hail of windshield.

4. The procedure was not performed because the pilots forgot to perform it: no action of the crew to prevent further descent at a vertical speed of more than 50 m / min, which led to the trigger warning signal (GPWS).

In a real flight on an aircraft, in addition to the controlling forces and moments that depend on the movement of the controls and their states, there are always random disturbances due to various factors. These include random components of the forces and moments of the propulsion system, as well as aerodynamic forces and moments that occur due to turbulent atmospheres, disruption of the original aerodynamic surface of the aircraft or failures and damage to the flight control system.

In catastrophic situations preceding an aircraft collision with an obstacle, serious consequences could be avoided if the crew were able to effectively and almost instantly change the dynamic properties of flight control. This can be achieved by applying active flight control methods while reconfiguring it in relation to the evolving flight situation. With the correct sequence of instructions from the flight manual, a crash could have been avoided or prevented.

During the flight, pilots can not always avoid the appearance of erroneous actions. Moreover, as shown by the statistics of the two emergencies, the duration of improper piloting of the aircraft increases with increasing number of simultaneously acting factors (in this case, failures).

In the event of two or three, or even more failures, there is a "factor overlay" (a set of simultaneously acting factors), as a result of which there is a large operational overload of crew members. The case of the Tu-204 in Moscow clearly shows that physically the commander of the aircraft must perform more than 70 operations (N), and the co-pilot - more than 20 operations to restore normal flight. From a physical point of view, it is almost impossible to complete a flight safely with so many actions to be performed one after another in an emergency. The problem of the operational workload of crew members is related to the specifics of the work of pilots - high tension, the special nature of piloting in short weather and bad weather - and is characterized by a large number of actions to be performed by a crew member. There is an operational load as a result of the appearance of factor overlays in flight, which, in turn, accompany special situations in flight. The Aircraft Flight Manual is one of the main documents used by pilots when piloting an aircraft. It describes the alternate flight procedures.

According to the aircraft flight manual, the main burden falls on the commander in special flight situations. In order to reduce the burden on the airplane commander, it is necessary to distribute responsibilities among the crew members when developing flight manuals, and to take into account the possibility of complex failures. One of the ways to increase the effectiveness of crew member training is the professional training of pilots on the criterion of counteracting factor overlays and the development of ways to optimize flight operations.

To identify the number of procedures that would not overload the pilot, it is necessary to compare his flights under the action of factor plates (complex failures on simulators) and in their absence. In the further development of optimization - to show and emphasize the presence of this phenomenon for removal in subsequent flights. Therefore, a program is needed to detect the effect of factor overlays in order to improve flight safety.

For the process of flight operation both on the plane and on the simulator, in the conditions of special situations in flight is characterized by a situation where the control of the ship changes in the process of developing a special situation. Therefore, it is most appropriate to use the method of adaptive control using intelligent technologies. The development of recommendations for pilots in the event of a difficult situation may be accompanied by the following points:

1. UNDERSTAND THE SITUATION: a crew member recognizes faults, names them clearly and precisely.

2. SAVE AIRCRAFT CONTROL: Mandatory when piloting a flight and co-pilot monitoring. But it is recommended to use the automatic control system as much as possible to reduce the load on the pilot.

3. ANALYZE THE SITUATION: the implementation of the procedure to eliminate a difficult situation in flight should be carried out only after accurate identification of the fault. WARNING! Pilots must wear oxygen masks and test all systems for "oxygen starvation" even if there have been no notifications.

4. TAKE APPROPRIATE ACTION: Of course, all difficult flight situations require immediate and correct action, but difficulties may arise if the pilot-in-command and the co-pilot take uncoordinated action. The commander's command must be clear, concise and take into account the confirmation time by the co-pilot for its execution before the next one. All crew members must report their actions or their inability to perform clearly and succinctly, without reducing or exaggerating the nature of the situation. This eliminates confusion and ensures effective, efficient and operational cooperation.

5. ANALYZE THE NECESSITY OF LANDING: procedures in the flight manual in case of a difficult situation may have several options: 1) send to the nearest airport for a safe approach to landing; and 2) do not send for landing. Then in case 2 the commander has to make a decision on safe landing.

Conclusions

In the first chapter, we learned that complex simulators are called simulators equipped with a mobility system. these are simulators of the highest level, and the cabin of the complex simulator is made in the form of a real cabin of the aircraft, that the main tasks of decoding flight information on complex simulators are: In addition, we analyzed in detail the step-by-step decoding of flight information based on Air Astana documentation and gained knowledge about the technical operation of FFS.

In the second chapter we learned about the system of crew training in case of a special case during the flight on FFS, about the existing methods of assessing the quality of training of pilots for special cases of flight on FFS. It will be demonstrated how Neumann-Pearson test can be used to calculate the choice threshold and concluded that the block of failures should include failures that do not affect the aerodynamics of the aircraft and the ability to control the aircraft. In Section 2.3, we in-depth analyzed the impact of the human factor on flight safety, demonstrated the SHEL model, and corroborated human factor information with various ICAO guidelines. At the end of this section, the component structure of flight safety was presented. At the end of the second chapter we got acquainted with the historical and technical development of flight parameters processing systems.

The third chapter was probably the most important for this work. The first section proposed various ways to improve the processing of flight parameters:

1) improvements in memory layout in buses (ARINC 717);

2) Vectorized Indexing;

3) Masking Corrupted data;

4) Dataframe estimation;

5) Alignment of parameter parts;

etc.

Section 3.2 will demonstrate the basis of algorithms for processing the flight parameters of the aircraft is a system for estimating the deviation from the normal distribution by the criterion of agreement "*xi*-квадрат" – χ^2 is equal to 2,478, and the probability p = 0.7. If $p \geq$ 0,10, then the hypothesis is considered plausible (at least not contrary to the studied data). According to the calculations of 10 flights, the criterion of agreement "*xi*-квадрат" – χ^2 is equal to 13.86, and the probability p is close to 0.02. If $p \leq$ 0,10, it is recommended to test the experiment (if possible) and in case noticeable discrepancies reappear, try to find a more suitable model for failure to describe statistics.

After these calculations, we can conclude that with simple failures enough normal distribution, failures should be trained to normal, failures should not be more than three, they should not affect the aerodynamics of the aircraft, duplicates should work and failures should not affect the system management."

Section 3.3 was devoted to the modernization of the aircraft crew training system in the case of a special flight case. This section highlights the flight operations to be performed by the crew in a special table, and after two plane crashes, we began to analyze them and concluded that in real flight on the aircraft, in addition to control forces and moments that depend on the movement of organs control and their states, there are always random disturbances due to various factors, these include random components of forces and moments of the mobile installation, as well as aerodynamic forces and moments due to turbulence, violation of the original aerodynamic surface of the device or failures and damage to flight control system, and in catastrophic situations preceding an aircraft collision with an obstacle, serious consequences could be avoided if the crew were able to effectively and almost instantly change the dynamic properties of flight control. After that, special recommendations were developed for pilots in the event of a difficult situation may be accompanied by the following points:

1. UNDERSTAND THE SITUATION: a crew member recognizes faults, names them clearly and precisely.

2. SAVE AIRCRAFT CONTROL: Mandatory when piloting a flight and co-pilot monitoring. But it is recommended to use the automatic control system as much as possible to reduce the load on the pilot.

3. ANALYZE THE SITUATION: the implementation of the procedure to eliminate a difficult situation in flight should be carried out only after accurate identification of the fault. WARNING! Pilots must wear oxygen masks and test all systems for "oxygen starvation" even if there have been no notifications.

4. TAKE APPROPRIATE ACTION: Of course, all difficult flight situations require immediate and correct action, but difficulties may arise if the pilot-in-command and the co-pilot take uncoordinated action. The commander's command must be clear, concise and take into account the confirmation time by the co-pilot for its execution before the next one. All crew members must report their actions or their inability to perform clearly and succinctly, without reducing or exaggerating the nature of the situation. This eliminates confusion and ensures effective, efficient and operational cooperation.

5. ANALYZE THE NECESSITY OF LANDING: procedures in the flight manual in case of a difficult situation may have several options: 1) send to the nearest airport for a safe approach to landing; and 2) do not send for landing. Then in case 2 the commander has to make a decision on safe landing.

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